Quantum interference between doubly and singly resonant top quark production

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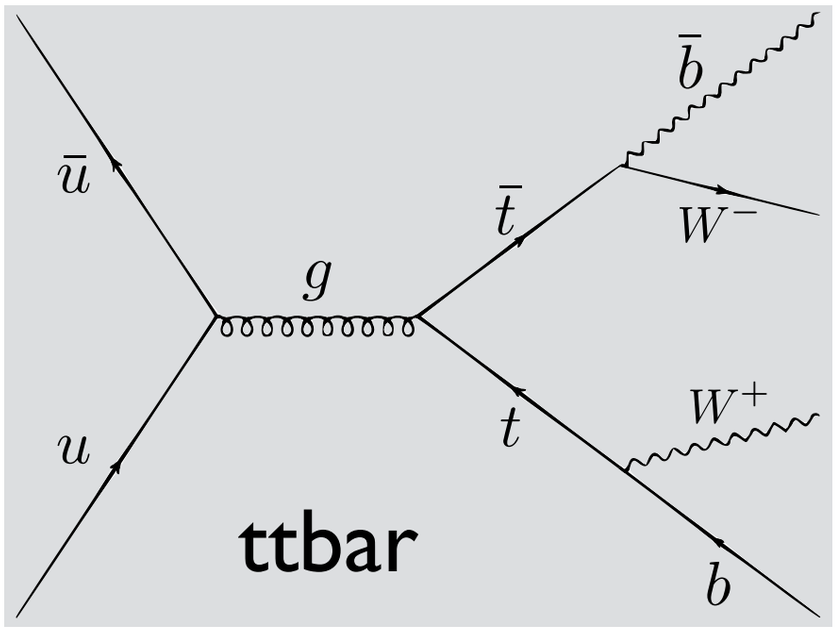
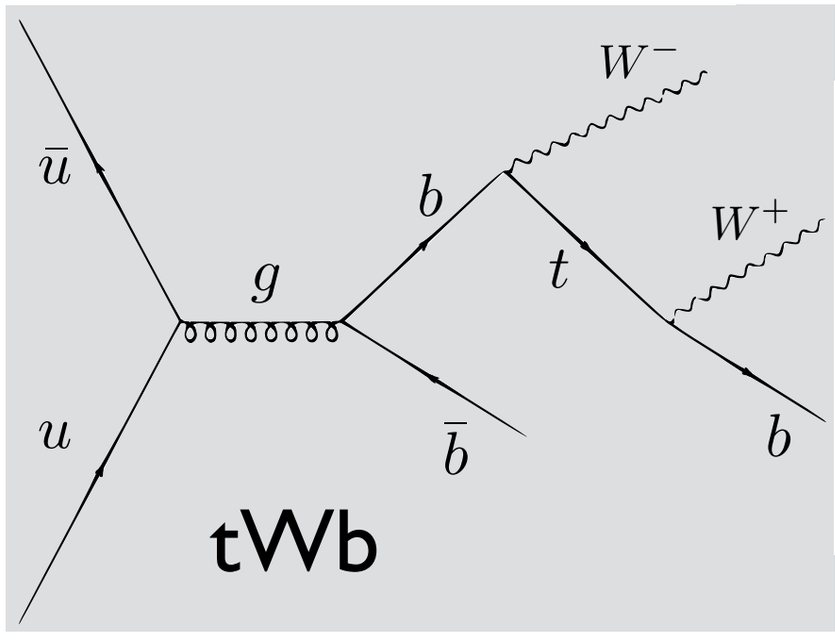
The ttbar and tWb processes have the same final state and thus there exists a quantum interference effect

$$|\mathcal{A}_{WWbb}|^2 \sim |\mathcal{A}^{(Wtb)}|^2 + |\mathcal{A}^{(t\bar{t})}|^2 + 2\mathcal{R}\{\mathcal{A}^{(Wtb)}\mathcal{A}^{(t\bar{t})}\}$$

The interference is largest when tWb "looks like" ttbar

ATLAS separately generates ttbar and Wtb at NLO+PS with Powheg+Pythia





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Interference effects are estimated by comparing two ad-hoc prescriptions:

Diagram Removal (DR) and Diagram Subtraction (DS)

Their difference is assigned as a systematic uncertainty

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Add'l details: Frixione et al. arXiv:0805.3067

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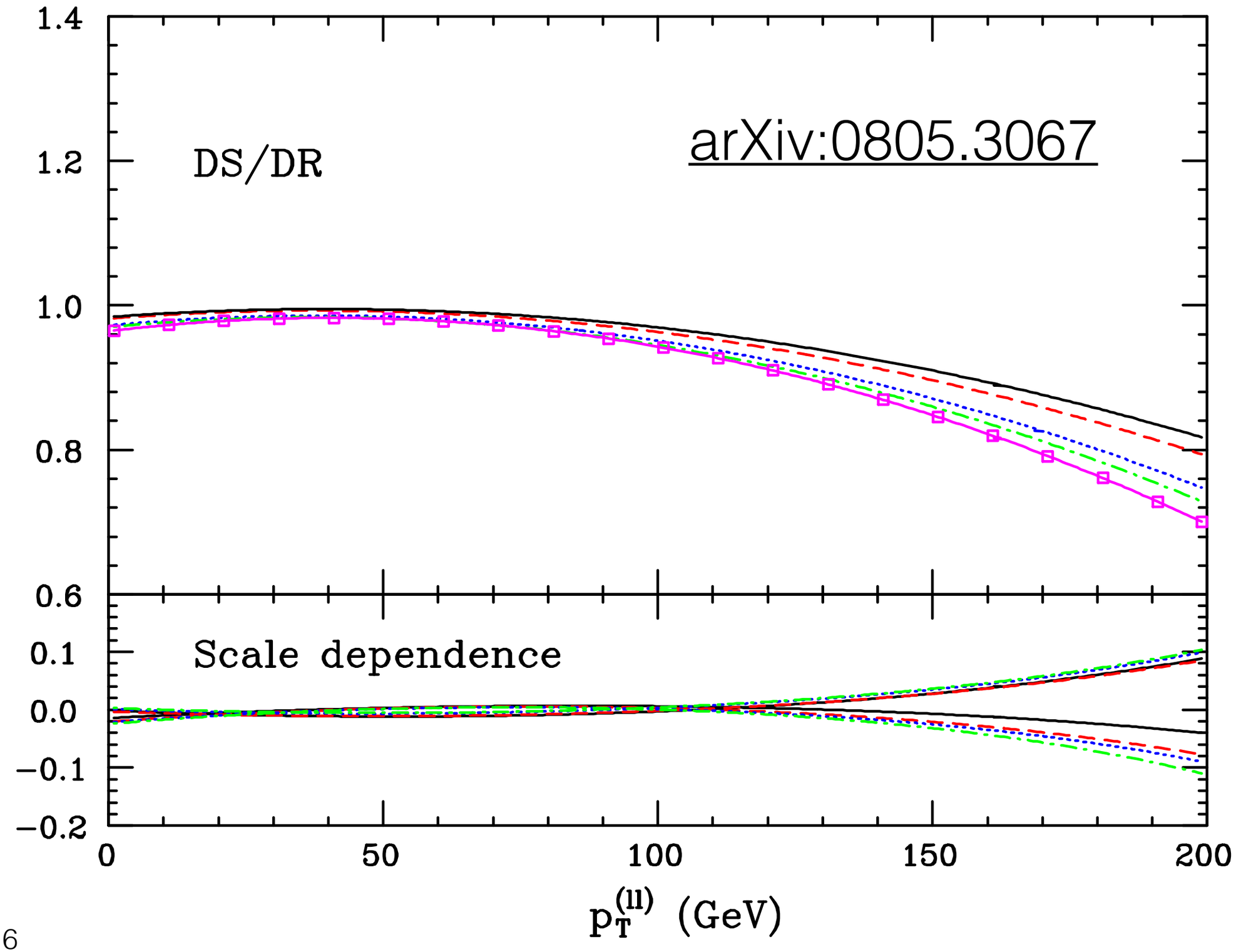
Define Diagram Removal (DR) single top to take only the $\mathcal{A}^{(Wtb)}$ piece

Define Diagram Subtraction (DS) single top as the entire expression, minus a gauge-invariant term that exactly cancels $\mathcal{A}^{(t\bar{t})}$ when $M^2_{bW} \to m^2_t$

DS/DR disagreement large in extreme (search) phase space



magenta = 2L2b inclusive selection

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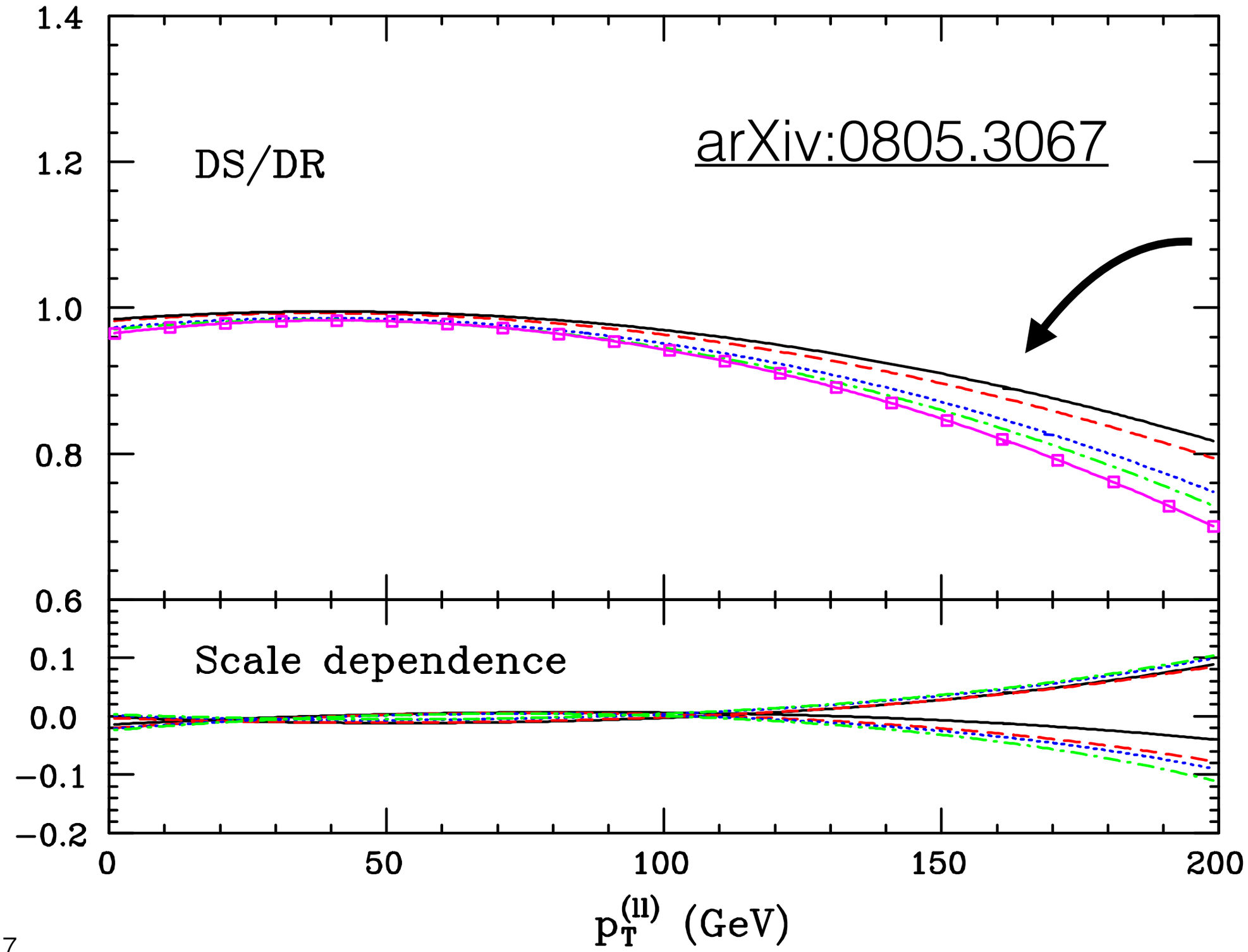


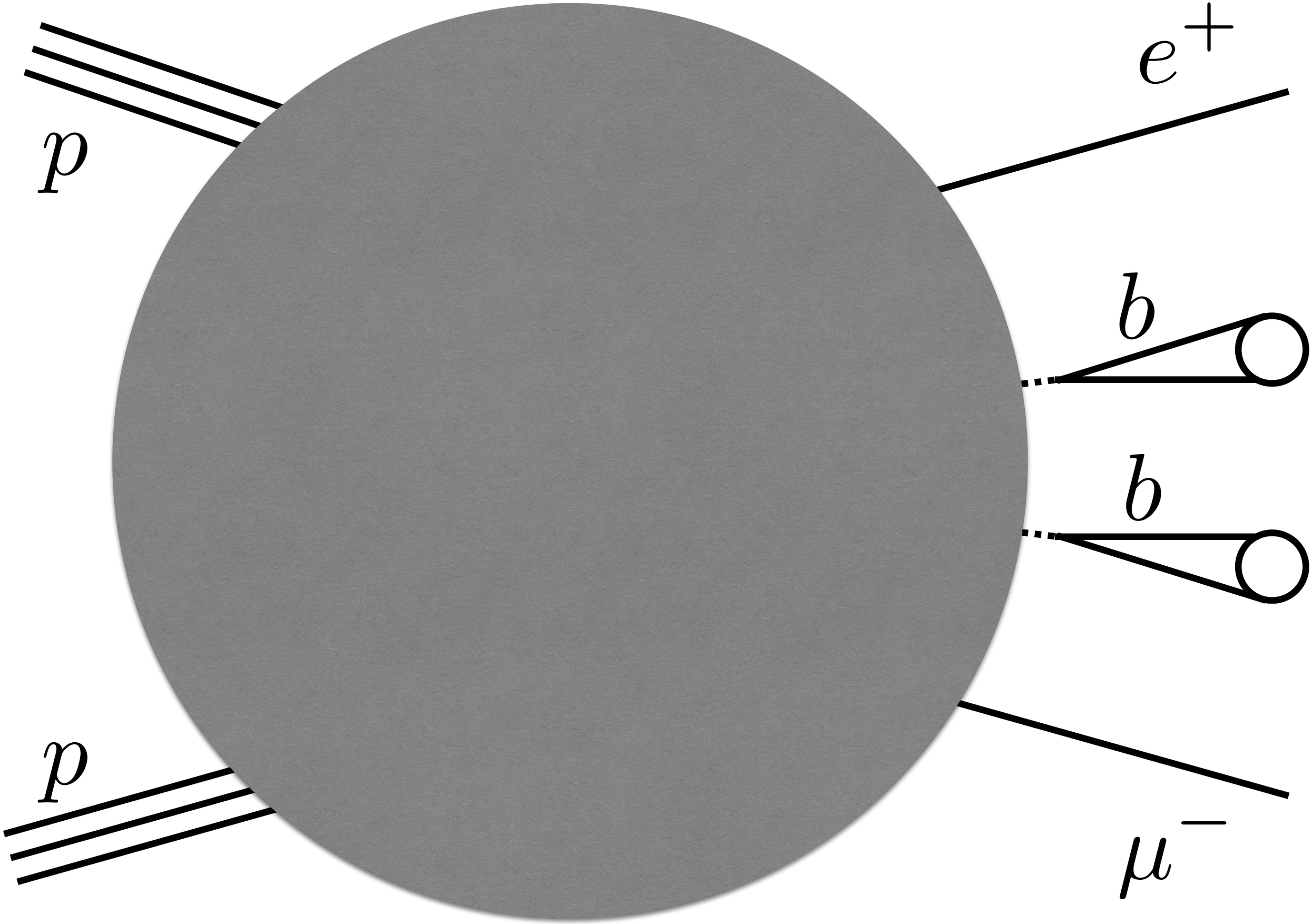
"Start worrying"

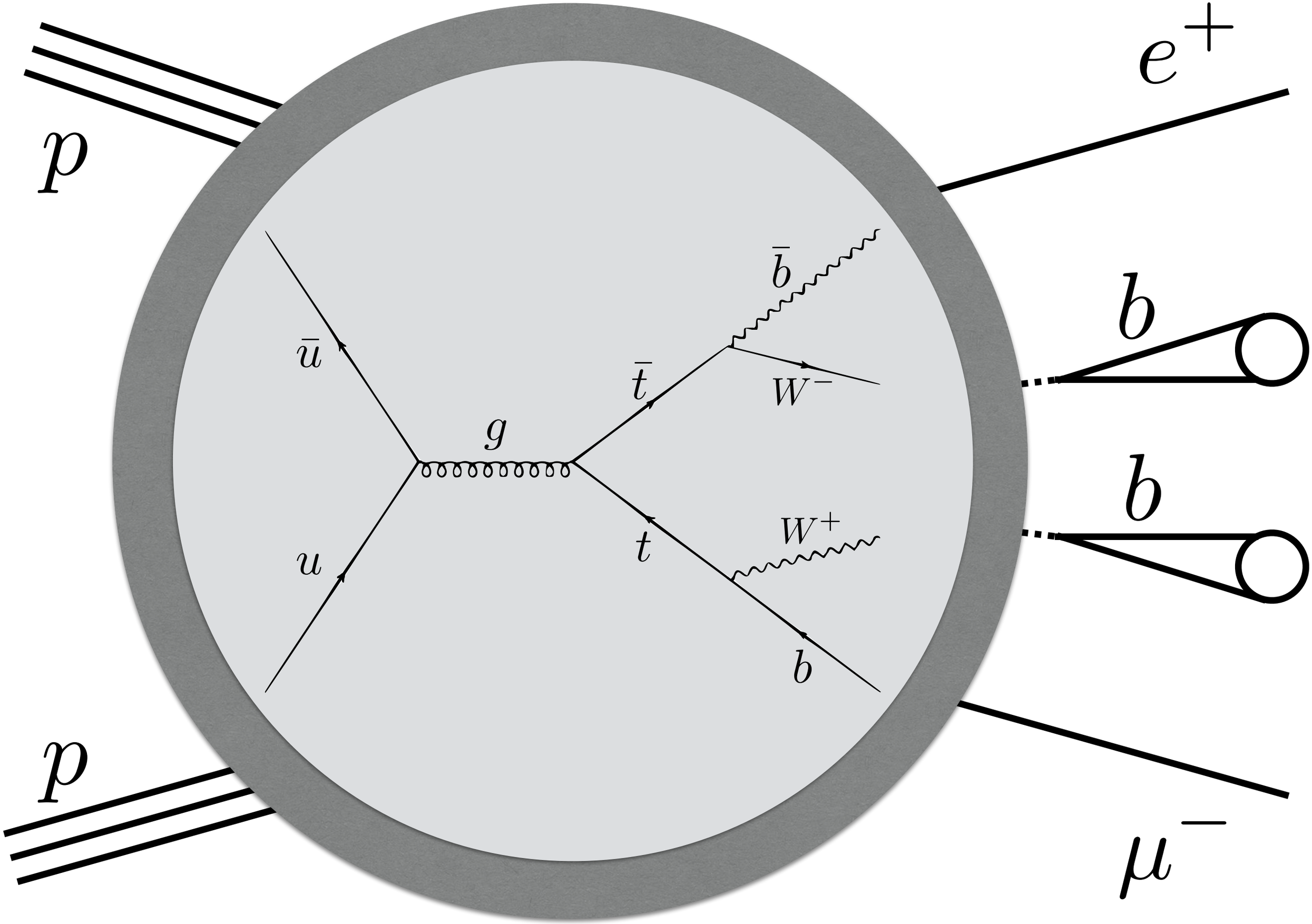
magenta = 2L2b inclusive selection

Herwig (Pennsylvania)

Run 2 LHC has provided us with millions of Wt events

Can we use this data to improve our understanding of tt-Wt interference?


e^+
b
b
p
p
μ^-


p
e^+
$\bar{u}$
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W^-
g
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t
W^+
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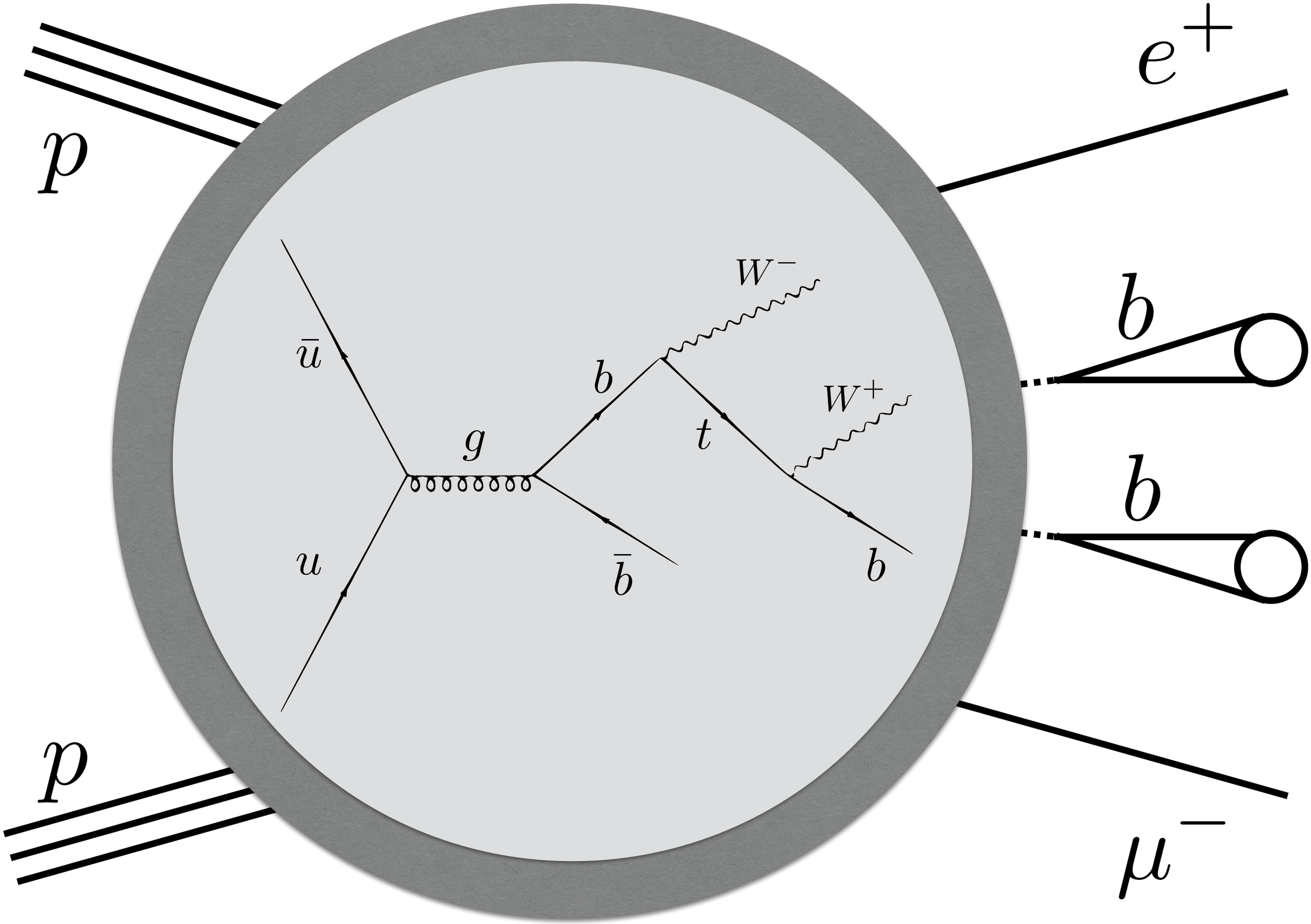
p
e^+
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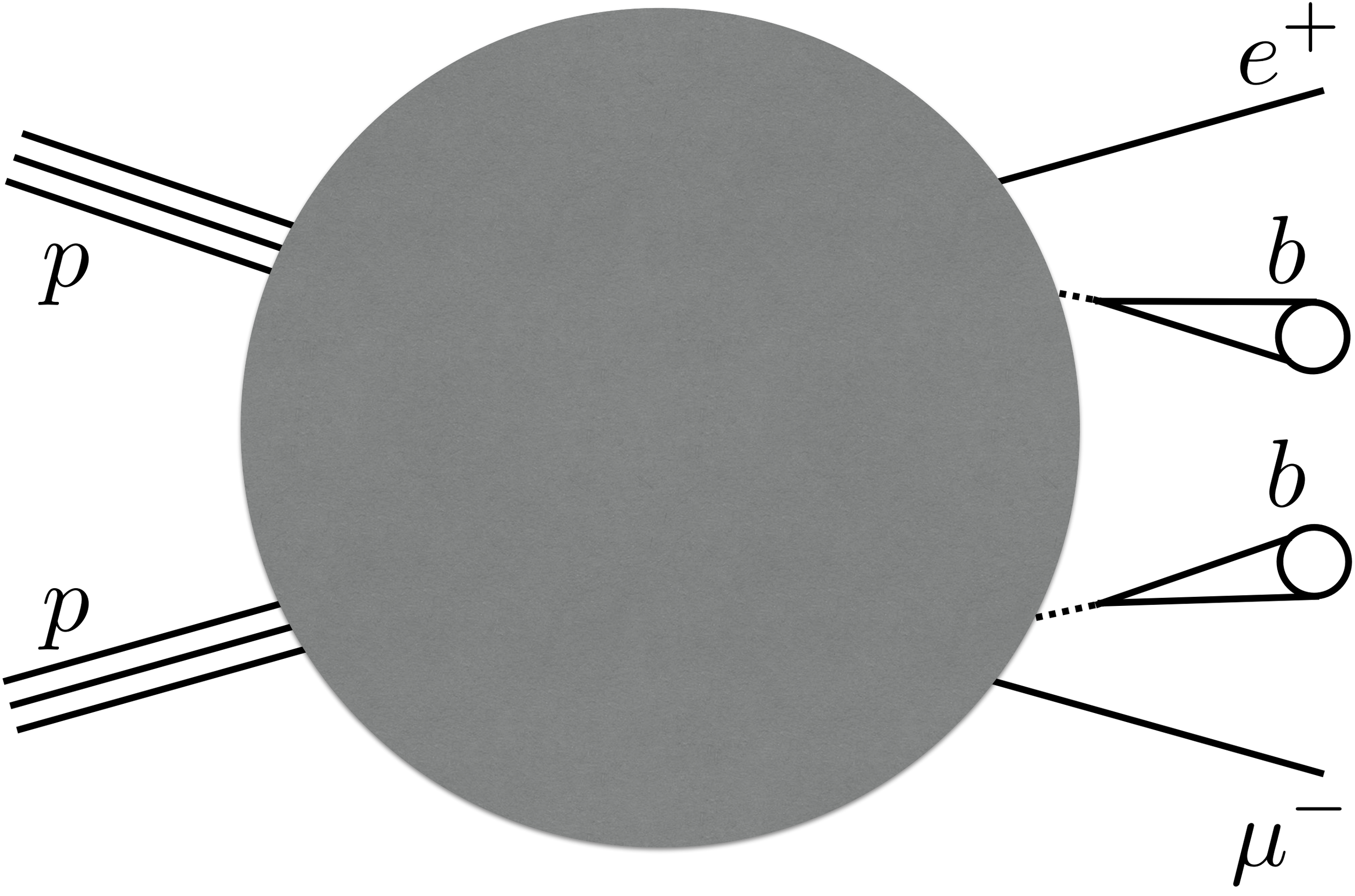
e^+
b
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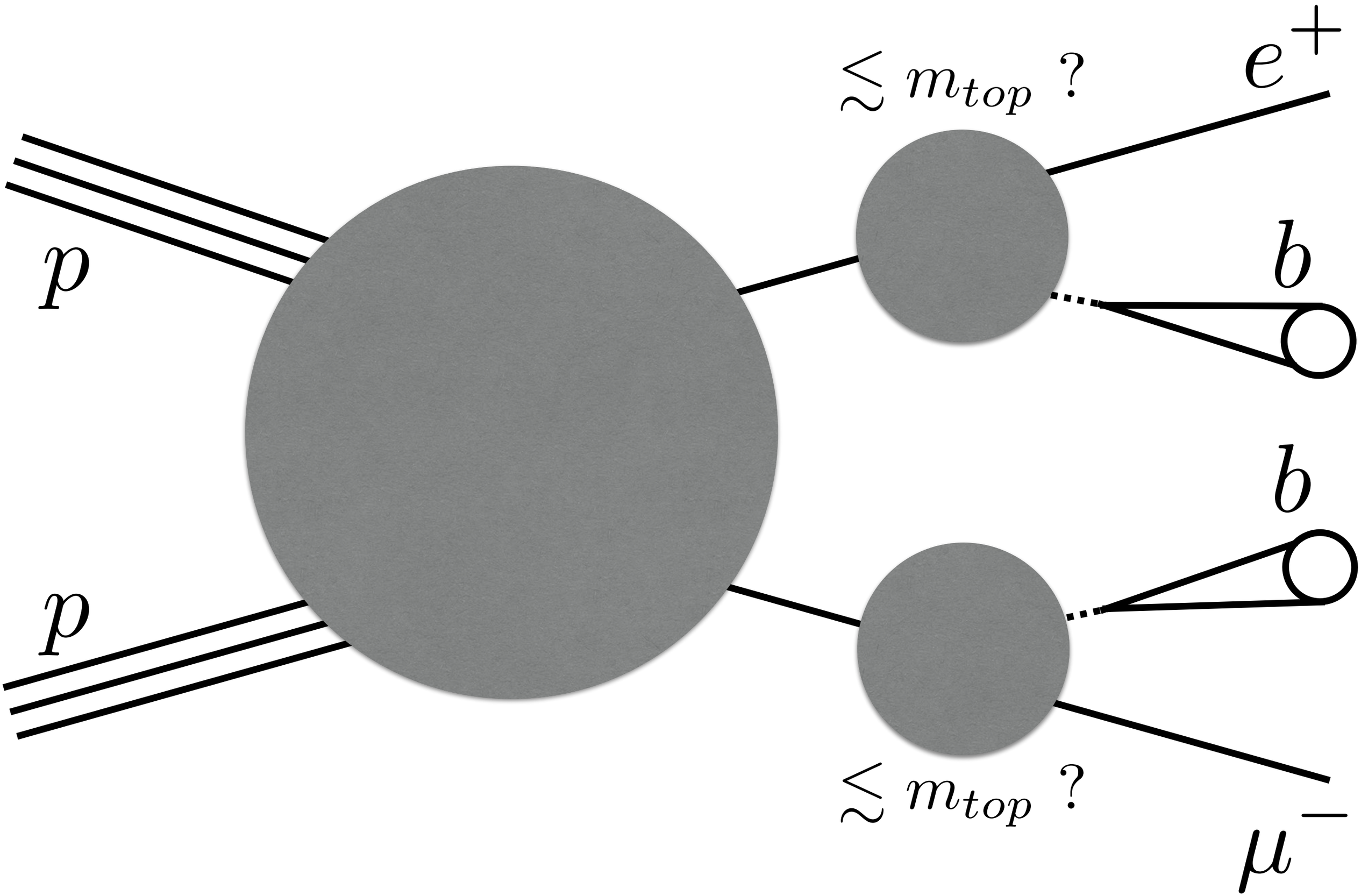
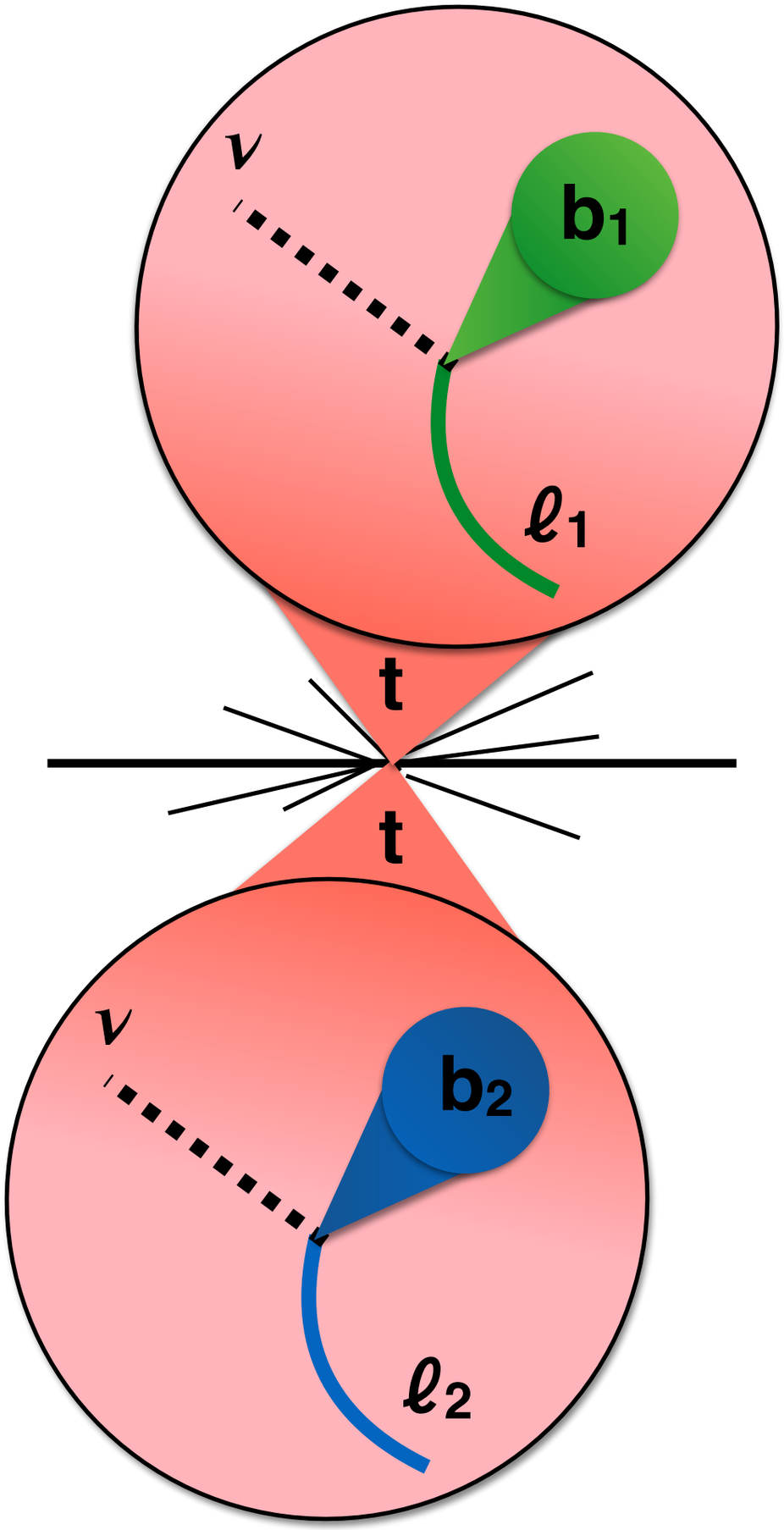
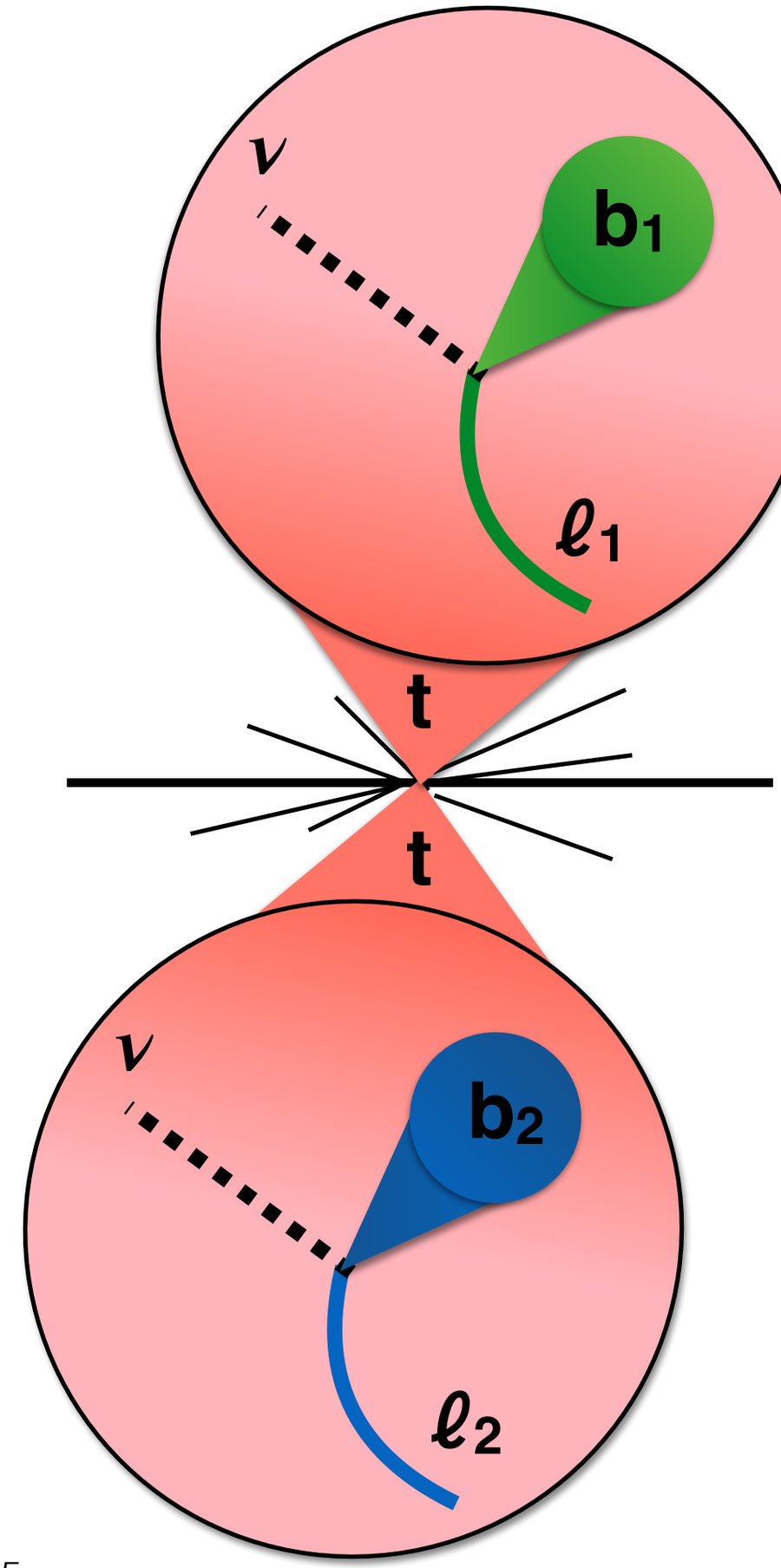
b
p
μ^-


$\lesssim m_{top}$?
e^+
p
b
b
p
$\lesssim m_{top}$?
μ^-



Let $m_{ij} = m(b_i, \ell_j)$, and define

$$\text{min-max}\, m(b, \ell)$$
$$\equiv \min\{\max(m_{11}, m_{22}), \max(m_{12}, m_{21})\}$$



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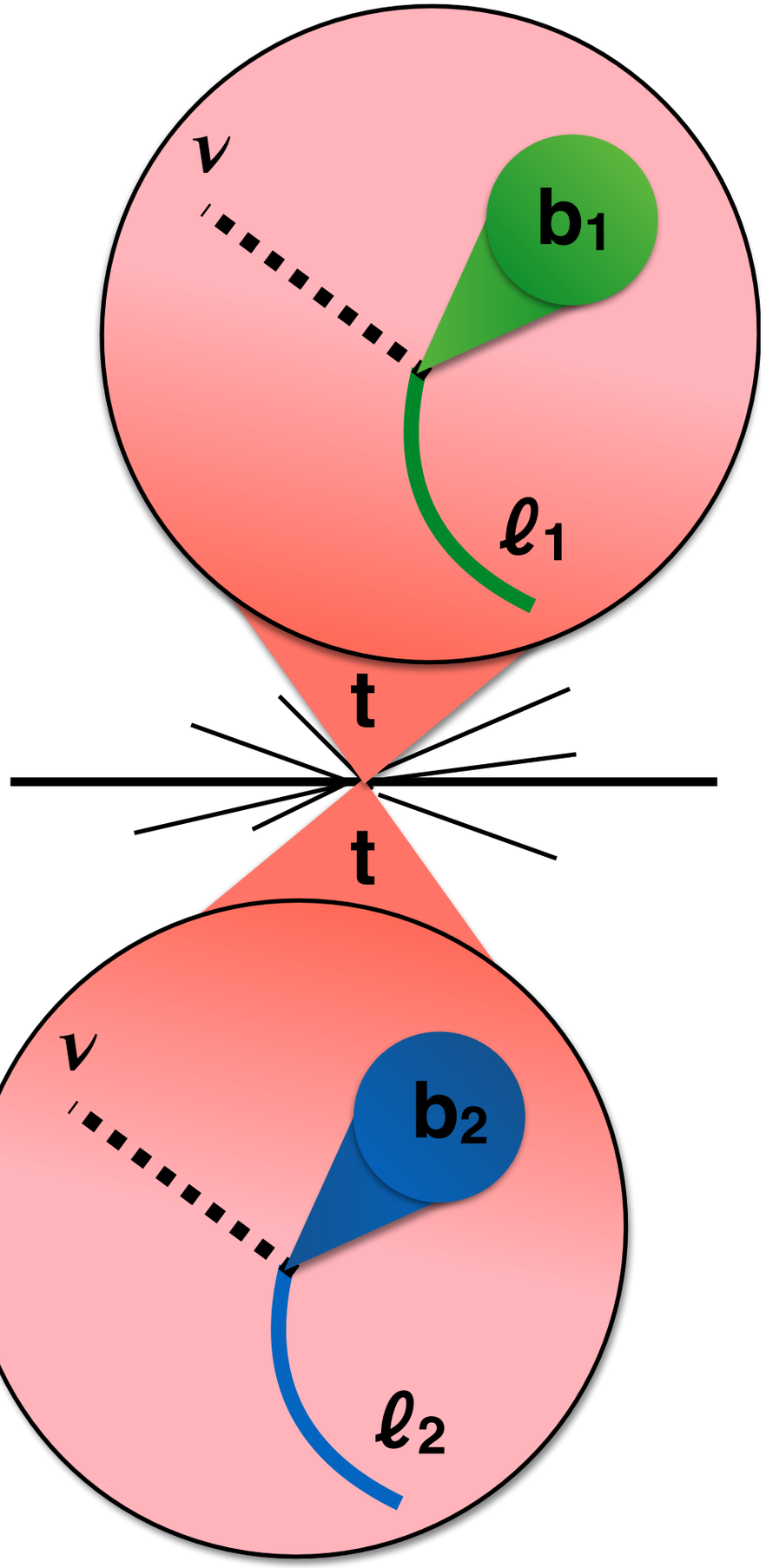
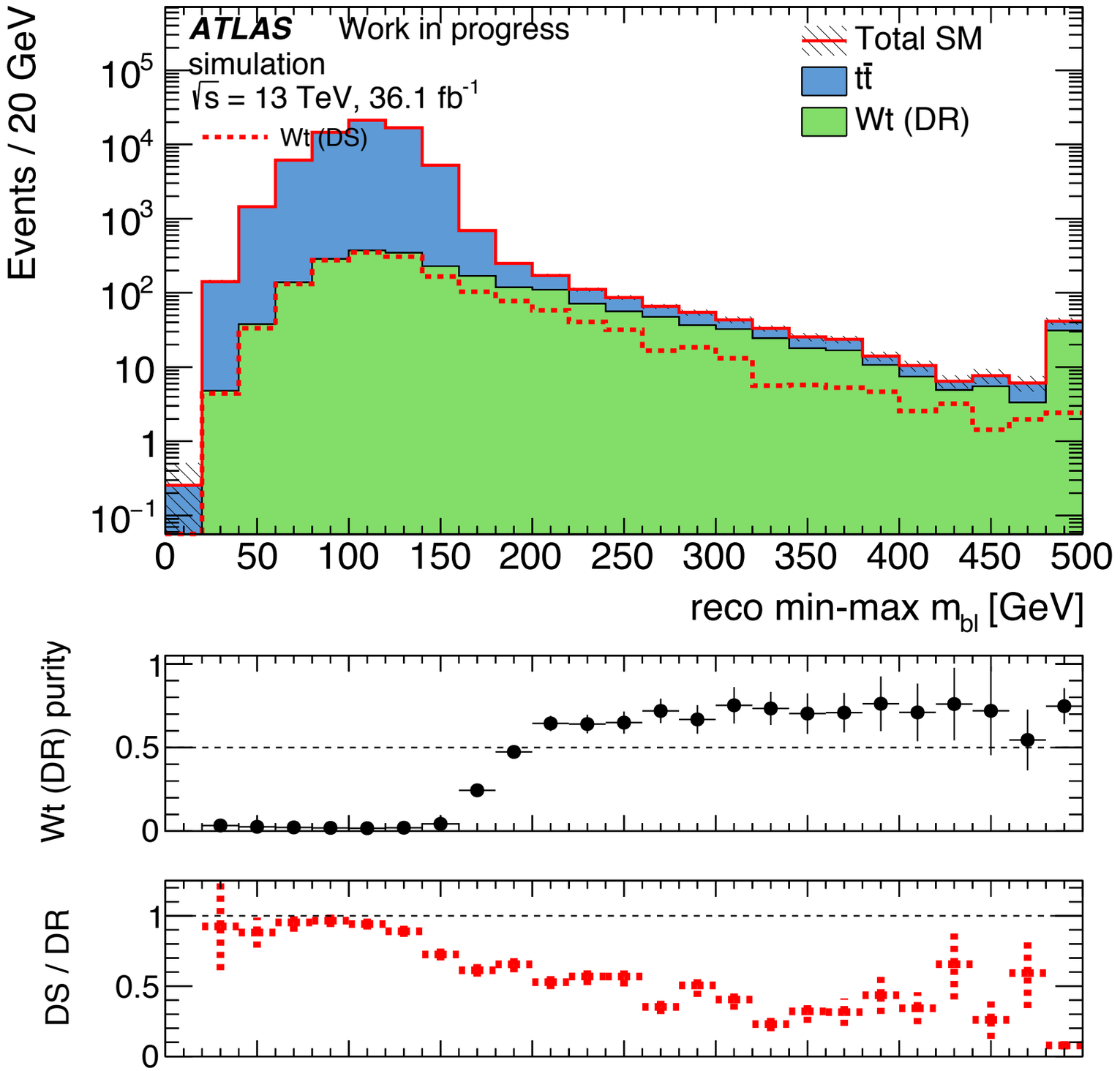
wrong pairing: m_{bl} usually large
correct pairing: m_{bl} bounded by m_{top}

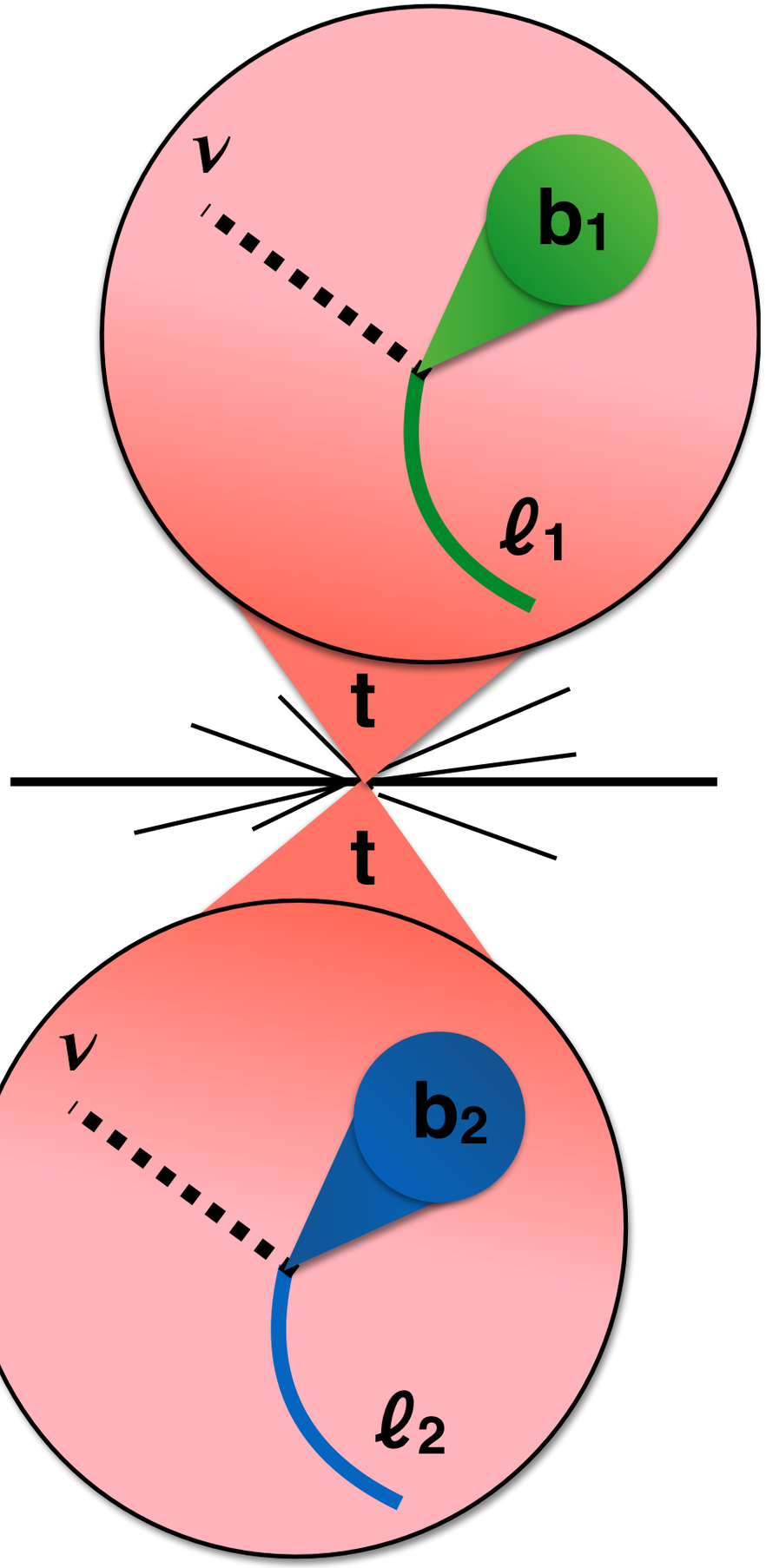
Important Properties:

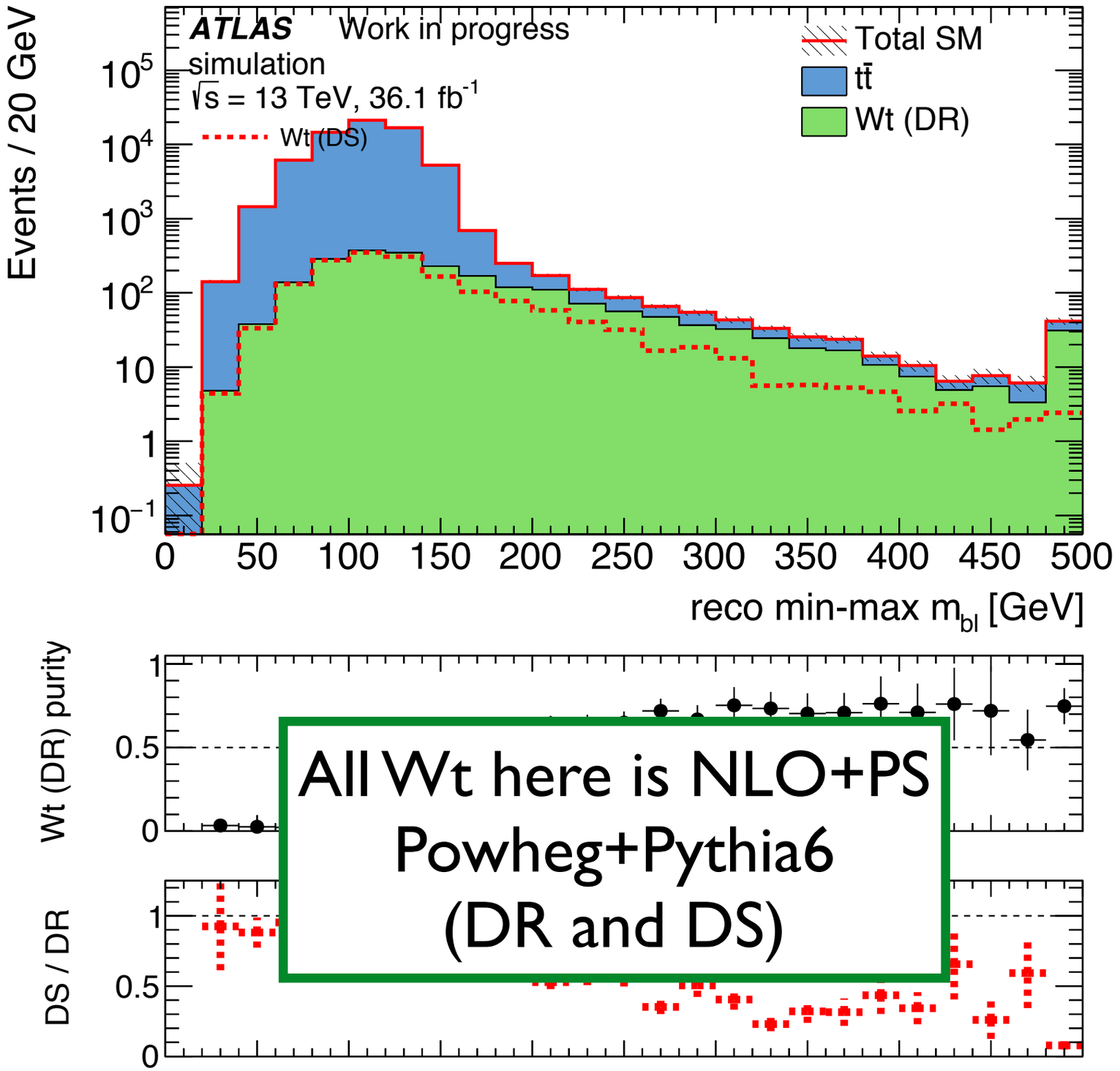
min-max $m_{bl} < m_{top}$ for ttbar events
not necessarily for Wt events!





Analysis strategy: measure this spectrum!





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Fiducial region:

exactly 2 leptons, *exactly* 2 b-tagged jets

$m_{ll} > 10$ GeV and $|m_{ll}-m_Z| > 5$ GeV

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exactly 2 leptons, *exactly* 2 b-tagged jets

m_{ll} > 10 GeV and $|m_{ll}-m_Z|$ > 5 GeV

Single lepton triggers

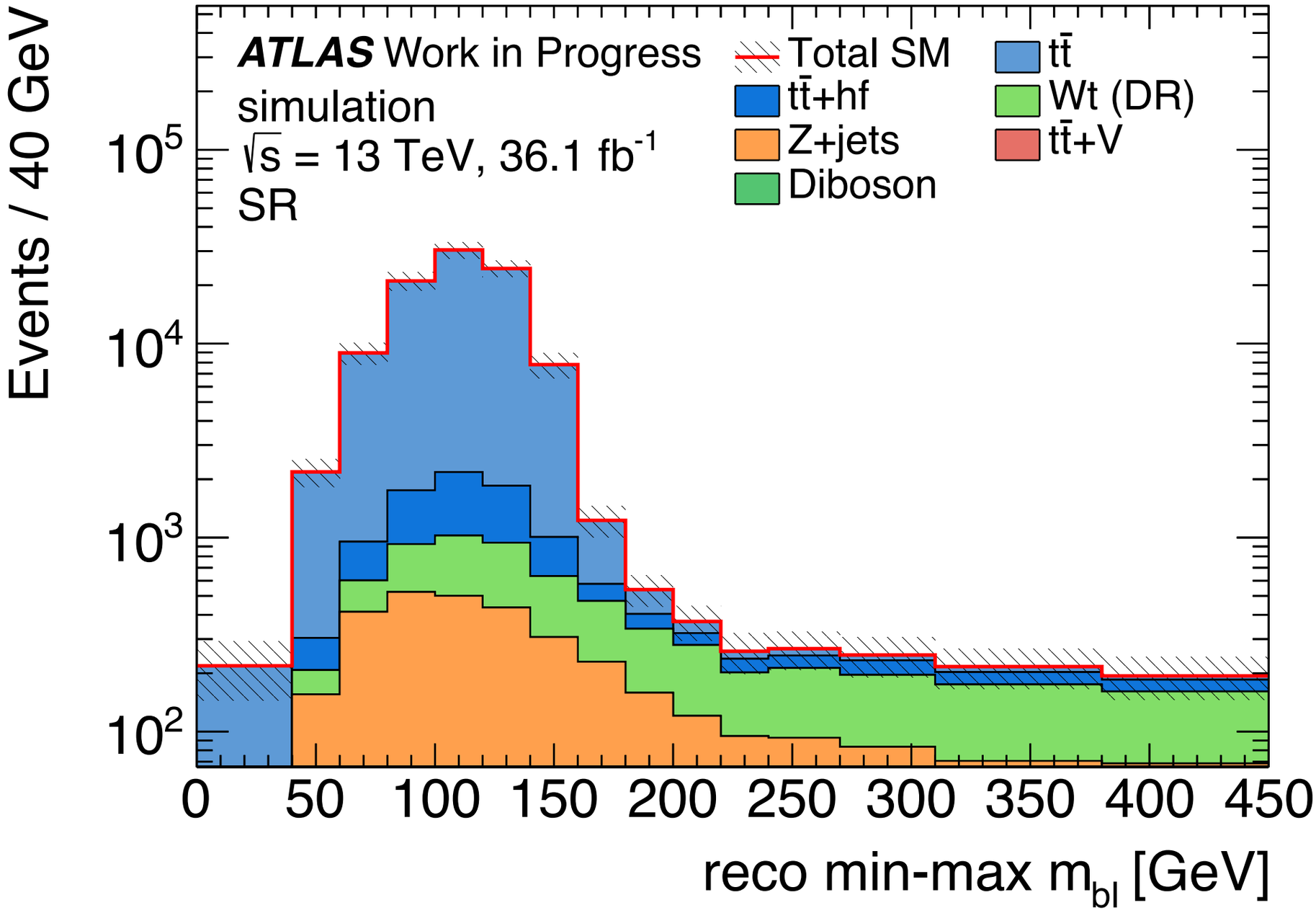
lepton p_T > 28 GeV

b-jet p_T > 20 GeV

tag at 60% efficiency WP, veto at 85%

ttbar and Wt are treated **together** as the signal process

dominant backgrounds estimated from data
using dedicated control regions (CRs)



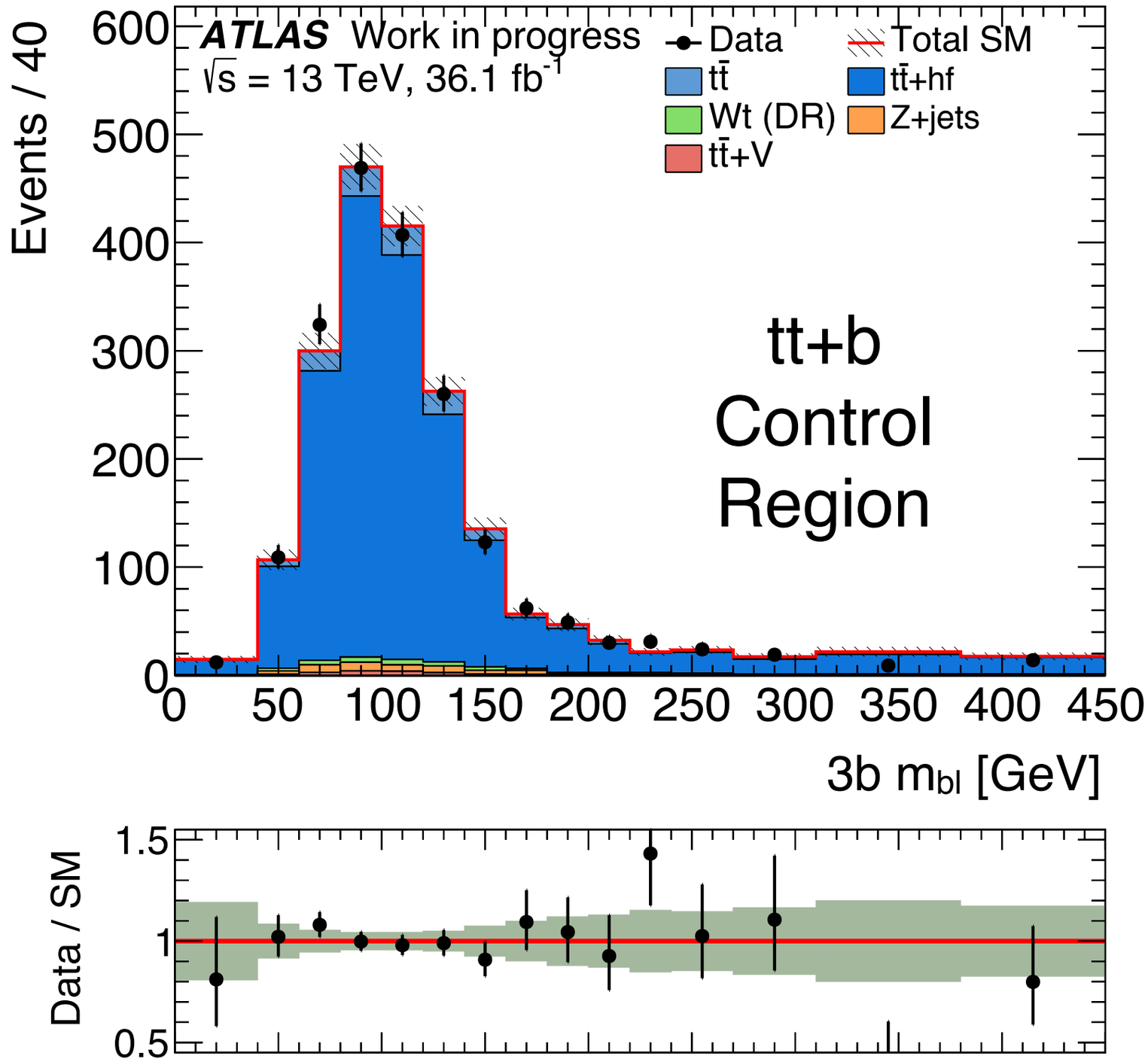
Estimating tt with additional heavy flavor

Problem:

if the identified b-jets aren't from top decays ttbar can pass the kinematic endpoint!

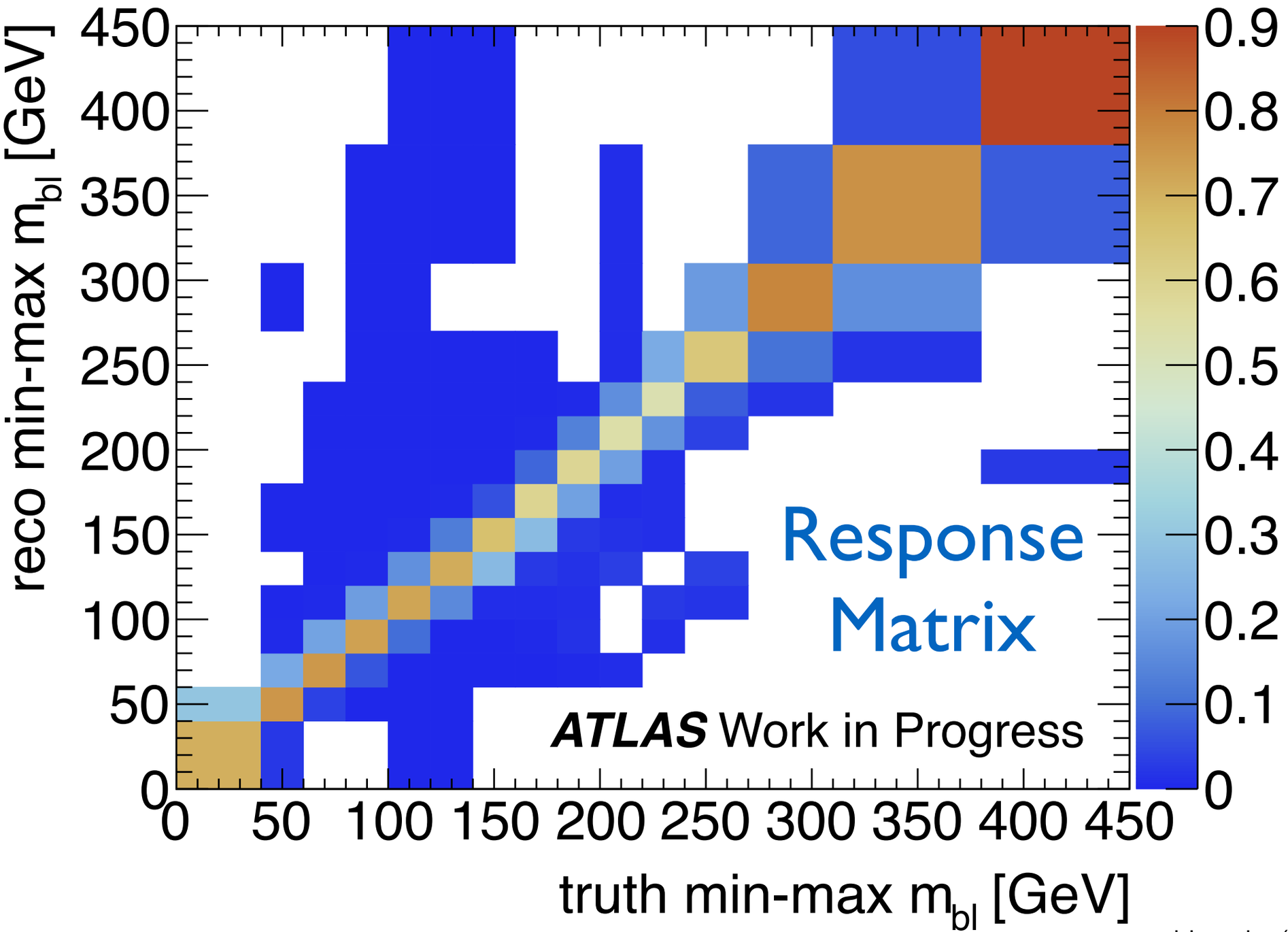
Solution:

normalize tt+b in a dedicated 3 b-jet CR



m_{bl} spectrum is unfolded to particle-level

(with ttbar and Wt treated together)

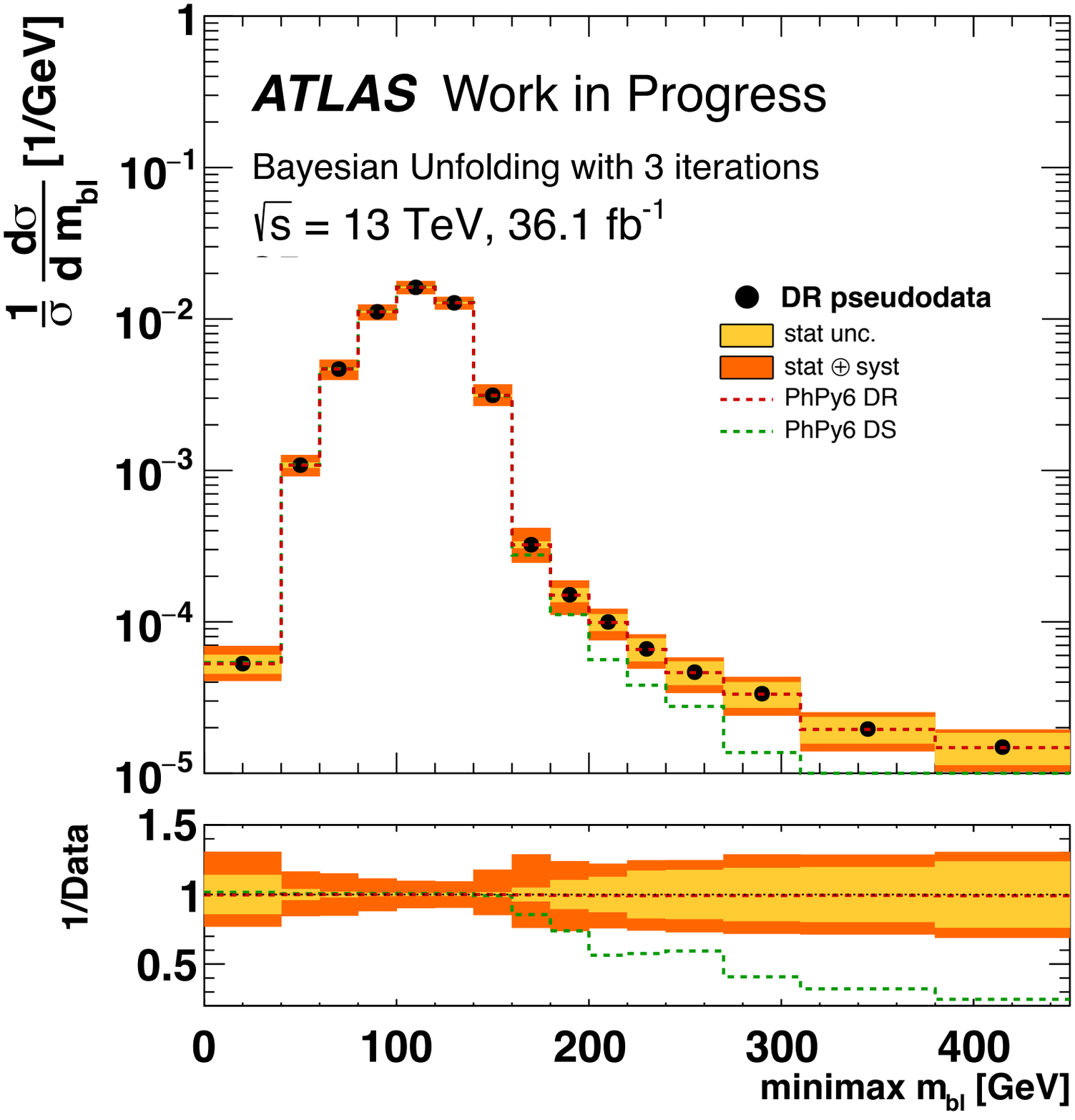


Results (blinded)

Total uncertainty in tail is dominated by data statistics

Sensitive to DR/DS differences: shape+normalization

Data compared to state-of-the-art generators



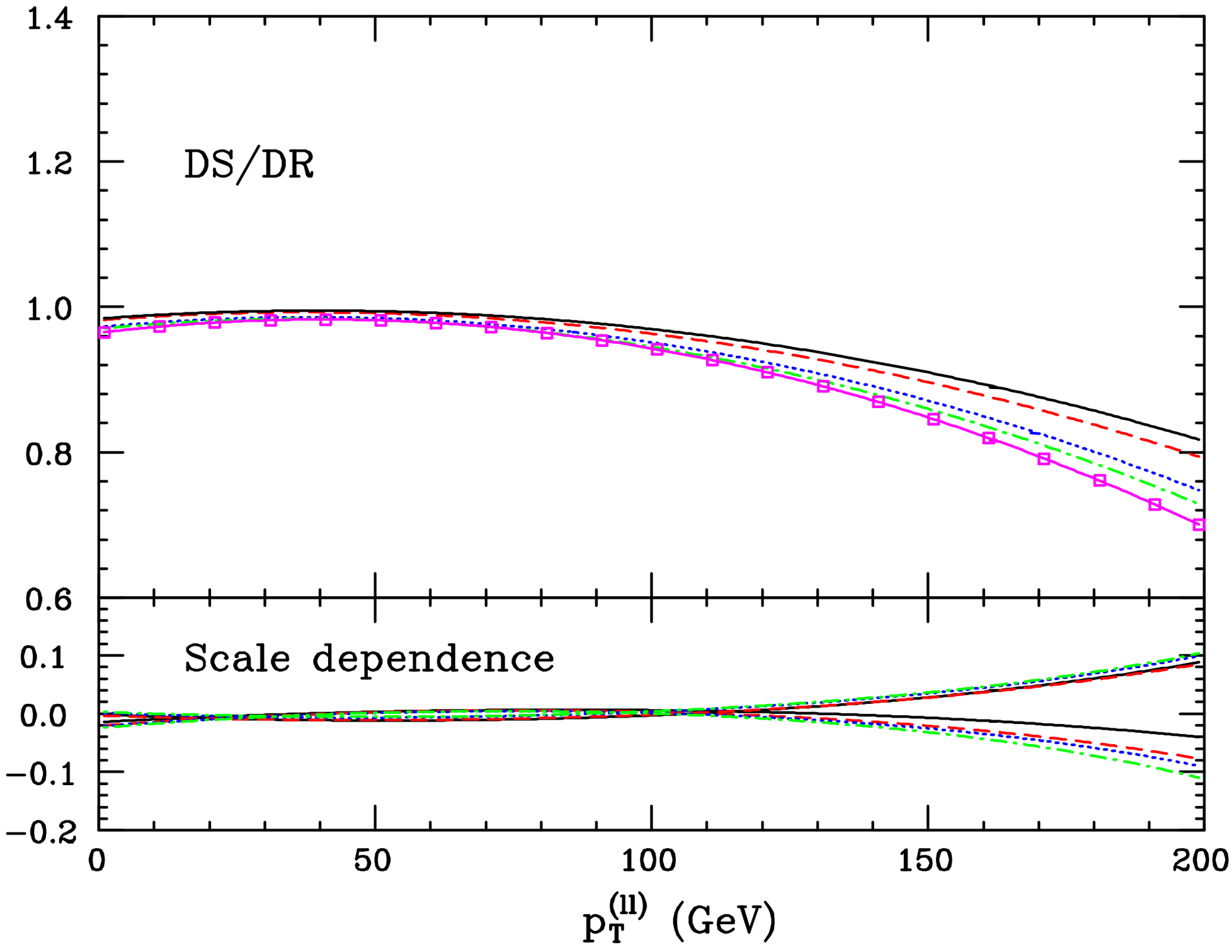
Conclusions

We present the first measurement of the WWbb final state in a region of maximal tt-Wt interference

Measurement is sensitive to the large differences between state-of-the-art generators

We expect to reduce the systematic uncertainty associated with ATLAS's treatment of the tt-Wt interference

Backup



Black solid, red dashed, blue dotted, and green dot-dashed lines correspond to $p_{\rm T}^{(veto)}$ = 10, 30, 50, and 70 GeV respectively. The magenta solid line with open boxes is obtained without imposing any veto.